Mission Operations Center and Ground Data System

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Downlink	
Data Rate	Low rate (min)=1k (2ksps); High rate (max)=500kbps (1Msps)
Coding	Reed-solomon & convolutional
Modulation	Low rate=NRZ-M, BPSK-modulated onto 1.7 MHz subcarrier, which is PM onto carrier (mod index=1.6 rad); High rate=NRZ-M, BPSK-modulated onto carrier
Required Eb/No	3.0dB
Margin (min)	3.0dB
Frequency	2.200-2.290GHz [2273.9MHz]
End-to-End Delay	See "SOC-MOC Interfaces" chart
Uplink	
Data Rate	2 kbps
Modulation	NRZ-M data BPSK-modulated synchronously onto 16 KHz sinewave subcarrier; Mod index = 1 rad
Coding	None
Margin (min)	7.0dB
Frequency	2.025-2.110GHz; [$f_{d/l}$*(221/240)=2093.8892 MHz]
Ranging*	
Ranging	Derived from uplink; PRN directly PM onto downlink carrier at 0.5 rad; Noise<3m, Bias<15m
Range-rate	Noise<3mm/sec

* Simultaneous Telemetry and Ranging at Low Rate

Command and Control Requirements (2 of 2)

- **Security**
  - **Unencrypted Uplink and Downlink**
  - **Uplink Authenticate Count Implementation**
  - **All Downlink Data Is Unclassified**

- **Standardization**
  - **CCSDS-Compliant**
  - **Compatible With NASA's Deep Space Network (DSN)**

- **Backward Compatibility**
  - **Compatible With Current BP Architecture**

- **Spacecraft Orbit**
  - **Elliptical e = 0.0119**
  - **Geosynchronous; i = 30.33° (Worst Case Injection Error)**
  - **View From BP (Mission Orbit): 6°< Elevation Angle <62°; 206°< Azimuth Angle <261°**

- **Spacecraft Mobility: Stationkeeping Maneuvers Every ~1.25 Years**

- **Channel Characteristics**
  - **Separate Virtual Channels for Bus SOH, Payload SOH, Mission Data**

Operations Concept

FAME
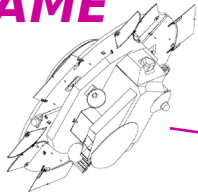
Telemetry, Tracking, and Commands

MOC
NRL Blossom Point Ground Station
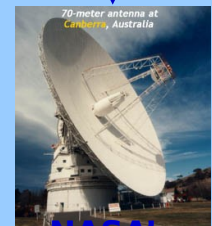**Blossom Point, MD**

Primary RF Front End

Backup RF Front End

Launch and Emergencies Only

JPL NOCT

SOC

- **Command Files**
- **Tasking Files**
- **Star Catalog Uploads**
  T1

S/C State of Health Monitoring and Command File Uplink 24/7
SOH Archive

FAME Science and Mission Planning Center
USNO, Washington, DC
Science Data Archive

- **Housekeeping Telemetry, Ground Station Statistics, Scheduling Info via Streaming TCP Socket Connection**
- **State Vector Files, Pushed via FTP**
- **Gzipped Mission Data and Housekeeping Telemetry Recording Files, Pushed via FTP**
- **S/C Bus SOH Reports**
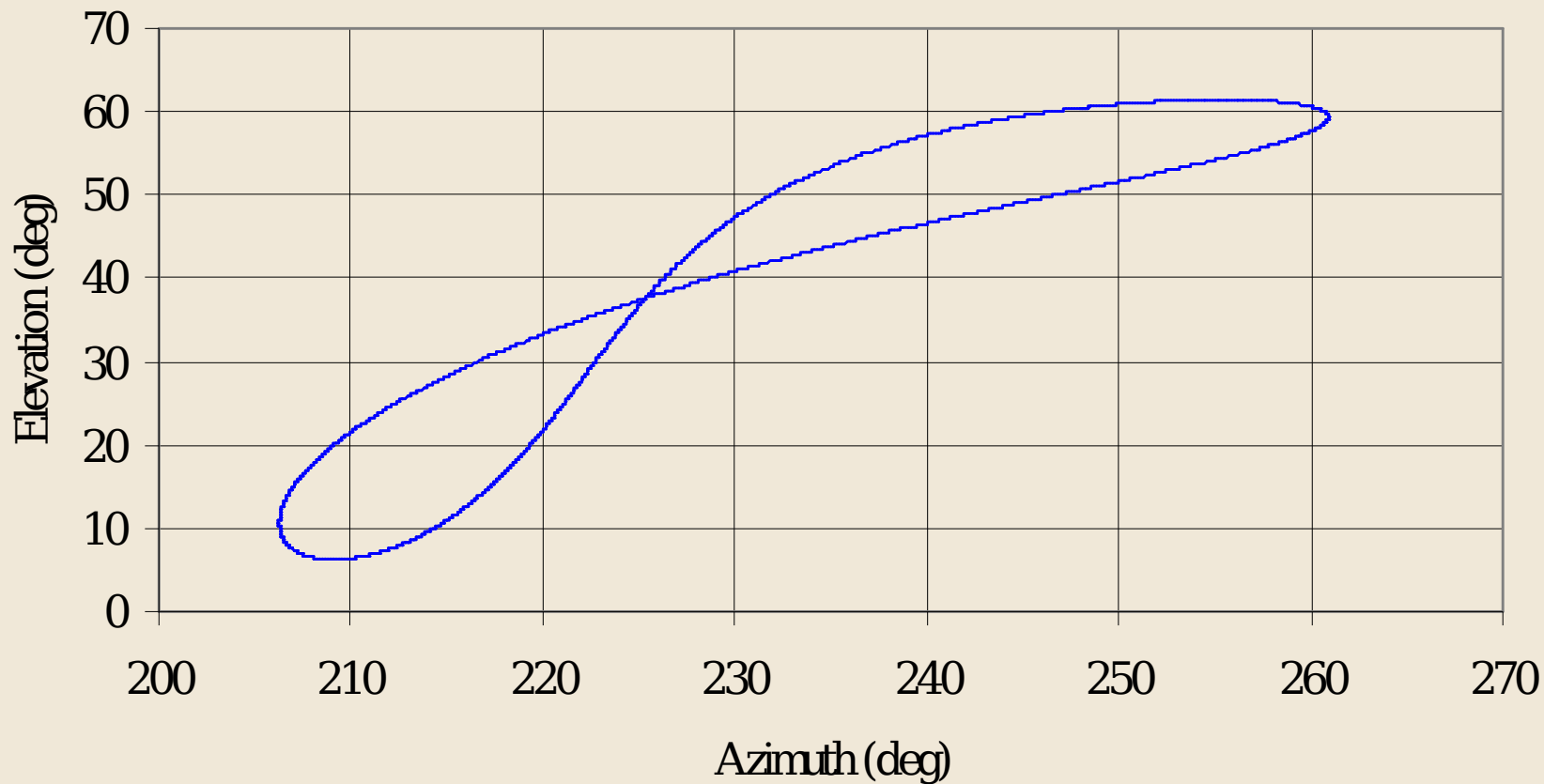- **Weekly Plan Files**

NASA's Deep Space Network

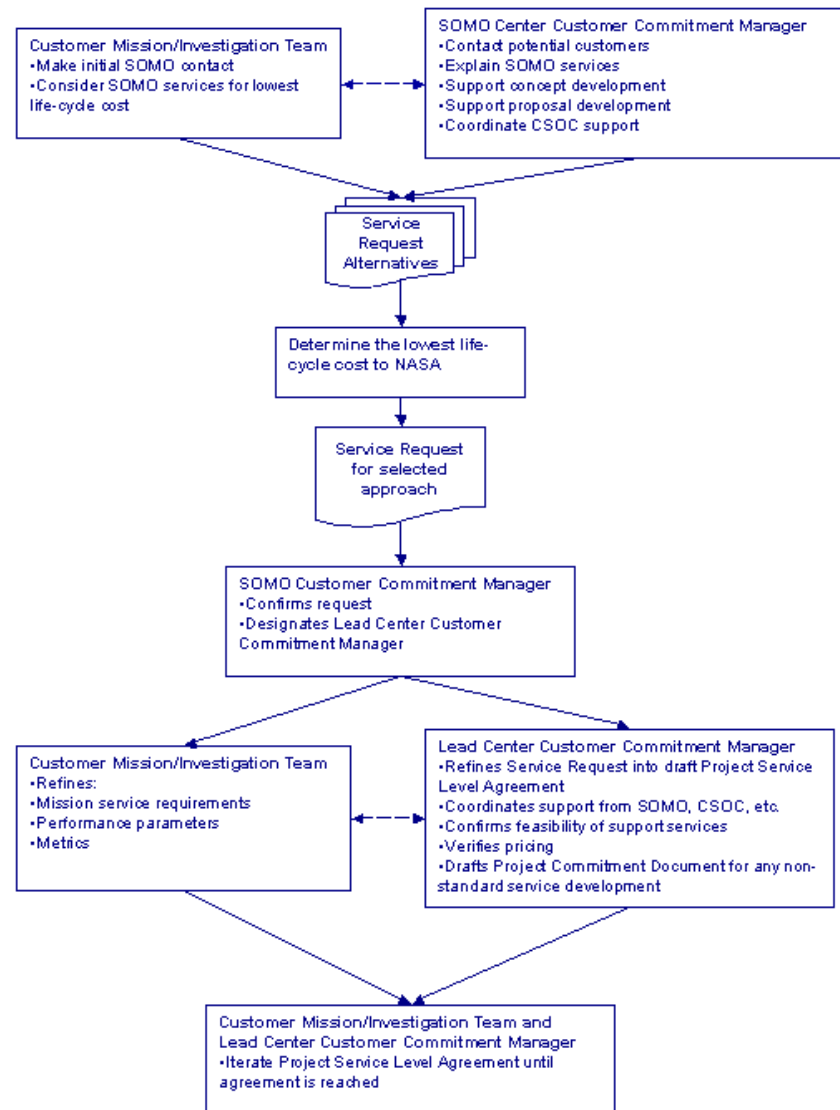FAME Apparent Trajectory from BP
LAN = 105.5° West

DSN Support Services Process

- **Project Service Level Agreement (PSLA)**

  - **Requests NASA Mission Operations and Ground Data Systems Support**

  - **Updated Yearly, or As Required**

  - **Current Version Dated 15 March 2001**

- **Project Commitment Document**
  - **NASA Response to PSLA**

FAME PSLA Is Signed and Submitted

Customer Mission/Investigation Team
- Make initial SOMO contact
- Consider SOMO services for lowest life-cycle cost

SOMO Center Customer Commitment Manager
- Contact potential customers
- Explain SOMO services
- Support concept development
- Support proposal development
- Coordinate CSOC support

Service Request Alternatives

Determine the lowest life-cycle cost to NASA

Service Request for selected approach

SOMO Customer Commitment Manager
- Confirms request
- Designates Lead Center Customer Commitment Manager

Customer Mission/Investigation Team
- Refines:
- Mission service requirements
- Performance parameters
- Metrics

Lead Center Customer Commitment Manager
- Refines Service Request into draft Project Service Level Agreement
- Coordinates support from SOMO, CSOC, etc.
- Confirms feasibility of support services
- Verifies pricing
- Drafts Project Commitment Document for any non-standard service development

Customer Mission/Investigation Team and Lead Center Customer Commitment Manager
- Iterate Project Service Level Agreement until agreement is reached

Mission Operations Center (MOC) Top Level Requirements

- **Purpose**

  – **Conduct Spacecraft Mission Operations From Launch Through End-of-Life**

- **Scope**

  – **Must Be Operational 365/24/7**

  – **Connectivity to Science Operations Center**

  – **Connectivity to NASA Deep Space Network**

- **Orbits and Navigation**
  - **Precision Trajectory Determination**
  - **Maneuver Planning and Evaluation**

- **Mission Planning**
  - **Planning Is Required for Each Mission Phase**
  - **Maintenance of S/C Activities Timeline**

- **Flight Operations**
  - **On-Board Resource Scheduling**
  - **Command Planning, Based on Science Operations Requirements and Tasking, While Maintaining Observatory Health and Safety**
  - **Provide DSN Operations Interface (Scheduling, Connectivity, Pre-pass Tests, Monitoring)**

- **Ground Systems Support**

    - **Maintenance and Logistics**

    - **Communications Support**

    - **Software and Hardware Configuration Control**

- **Data Management**

    - **Telemetry Processing**

    - **Science Data Processing**

    - **Console Logging**

    - **Data Display**

    - **Data Formatting, Archival, Distribution**

    - **Reporting**

- **Configure and Control Ground Station Equipment**

- **Format and Uplink Immediate and Stored Commands**

- **Load and Verify Spacecraft Memory**

- **Extract Housekeeping Telemetry Data for Display and Limit Checking at MOC**

- **Collect, Record, and Distribute All Spacecraft and Payload Data to SOC**

  - **Store Incoming "Raw" Data**

  - **Realtime Housekeeping Telemetry**

  - **Mission Data and Recording Files**

- **Process Tracking Data 10min*3/day**

- **Distribute to SOC**

  - **Ground Station Equipment Statistics**

  - **"Pass Plans"**

  - **State Vector Files**

  - **S/C Bus SOH Reports**

  - **Weekly Plan Files**

- **Receive From SOC**

  - **Uploadable Command Files**

  - **Uploadable Star Catalog Updates**

  - **Tasking**

Mission Operations Center Implementation

- **Common Architecture for Bus Integration and Test (I&T) and Mission Operations**

- **Members of the Mission Operations Team Participate in Spacecraft I&T**

- **Existing Infrastructure of NRL's Blossom Point Ground Station, NASA Deep Space Network, and NISN Is Used to Support FAME**

- **COTS Software and Hardware Used to Implement Many Functions of the FAME Ground System**

- **Includes Use of Commercial Workstation Operating in a Networked Environment Using Open Operating System to Conduct Tasks in a Distributed Fashion**

Blossom Point
Mission Operations Center (MOC)

Redundancy Not Shown

New Equipment

SOC-MOC Interfaces

- **Controlled by SOC-MOC Interface Control Document**

- **Preliminary ICD Is Available**

- **Covered in SOC Presentation**

Test/Simulations/Rehearsals Requirements

- **Ensure Safe and Reliable Spacecraft and Payload Operations**

- **Personnel Training and Practice**

- **Mission Compatibility**
  - **Exhaustively Check Out All Operational Elements**
    - **Software**
    - **Hardware**
    - **Man-Machine Interfaces**
    - **Operations Procedures**

- **Mission Readiness Demonstration**

Incremental Simulation Phases

- **Stand Alone Testing**

    – **Tests Each Operational Element (SOC, MOC, GDS)**

- **Compatibility Testing**

    – **Testing Between Elements (SOC-MOC, MOC-GDS, GDS-S/C)**

- **Integrated Simulations**

    – **Testing and Training Between Larger Segments (SOC-MOC-GDS)**

- **Mission Rehearsals**

    – **Highest Level of Simulation**

    – **Includes External Organizations (DSN)**

Candidate FAME Simulation Scenarios

- **Launch**

  - **Nominal Launch**

  - **Launch Slip**

  - **Off-Nominal Insertion**

  - **Abort and Reschedule**

- **Mission Orbit Insertion**

  - **AKM Burn Misalignment**

  - **Burn Length Variance**

- **Nominal Mission**

  - **"Day in the Life"**

  - **Anomalies**

Issues

- **None**

Development Milestone Schedule

- **6/02**   CDR
- **1/03**   Pre-compatibility Test
- **5/04**   Factory Compatibility Test
- **6/04**   BP Hardware/Software Upgrades Complete
- **6/04**   Rehearsal I (Nominal Ops)
- **7/04**   BP Antenna System Testing Complete
- **7/04**   DSN Interface Testing Complete
- **8/04**   Rehearsal II (Launch)
- **9/04**   Launch Base Compatibility Test
- **9/04**   Rehearsal II (Nominal Ops)
- **9/04**   Rehearsal IV (Launch)
- **10/04**   Launch
  - Dress Rehearsal with KSC
  - Mission Rules and Constraints Definition Complete
  - On Orbit Handbook/User's Guide Complete
  - Final Mission Timeline Complete
  - Operator Training Complete

Backup

Mission Operations and Ground Data System Trades

Function	Considerations/Constraints	Trades	Results
Data Transport & Delivery	Quantity and rates of data	Process telemetry at ground station v. control center	See Operations Concept
	Location of ground system elements	Choose type of communication links	Dedicated gnd system for 24 hour coverage, co-located with MOC; SOC located within driving distance
	Compatibility between space and ground elements	Design s/c for compatibility v. modify ground system	Transponder is "off-the-shelf"; mods to gnd system relatively inexpensive
Mission Control	Complexity of mission	Shared v. dedicated resources	Dedicated, due to availability
	Operations and maintenance philosophies	Redundancy v. allowable system downtime	Chosen gnd system (BP) has built-in redundancy and sparing policies
Spacecraft Planning & Analysis	Complexity of spacecraft bus	Level of ground automation	
	Orbit	Sophistication of software	See Orbit Concept
Payload Planning & Analysis	Type of payload	Level of onboard autonomy	
	Orbit	Level of ground automation	All actions planned on ground and uplinked as required; orbit design does not require "real-time" actions
Data Processing	Location of users (co-located or external)	Process data in MOC v. dedicated POCC	See Operations Concept
	Quantity of payload data	Process data in real time v. post-pass	See Operations Concept
Navigation Planning & Analysis	Orbit	Internal v. external orbit determination	Capability exists @ BP; stable orbit
		Ground v. onboard processing	Capability exists @ BP; stable orbit
	Required knowledge of orbit	Antenna angle data only v. ranging and doppler systems	Need all
Archiving	Quantity of data	Store raw v. processed data	Long-term raw available offline; most recent accessible online
	Compatibility with existing recorders	Type of storage media	Using readily-available COTS storage technologies.
	Duration of storage	Type of distribution & location of storage/transportability	See Data Archival Plan

Completed at PDR
Completed at SRR

Flight Operations Team Training

- **Integration Mission Team Approach**

  - **Training and Organization of the Flight Operations Team (FOT) Are Essential for Risk Mitigation**

  - **Mission Operators Are Critical Part of the Mission Design Team**

  - **Participation by Operators in Definition, Development, Testing, and Pre-Launch Mission Phases**

    - **Review Design Decisions and Their Effect on Mission Operations**

    - **Ensure That Money Saving Measures in the Space Elements Don't Drive up Costs for Ground Operations**

- **Blossom Point Personnel Have Many Years of Experience in Operating and Maintaining Many Spacecraft Types, Including Cross Training on BP Ground Systems**

  - **Will Be Trained for the Specifics of the FAME Observatory**

- **Free Exchange of Ideas Between Spacecraft Bus Engineers, Payload Engineer, and Operators**

Flight Operations Staffing
Nominal Mission

	Day Shift (0800-1600)	Swing Shift (1600-2400)	Night Shift (0000-0800)
Flight Ops Mgr	0.5 FTE		
S/C Specialist	1.0 FTE		
S/C Specialist	1.0 FTE		
Mission Analyst/Planner	0.5 FTE		
Maintenance Engr	0.25 FTE		
Console Operators	0.25 FTE	0.25 FTE	0.25 FTE

Monday - Friday Plus On-Call

0.25 FTE Scheduled Off

365 Days/Year

Simulation Development Process

Simulation Planning

FAME Mission Simulation Requirements
- Training
- Check out
- Proficiency

Simulation Definition
- Data
- Facilities
- Schedule
- Personnel
- Communications
- Evaluation Criteria

Simulation Script Development
- Description
- Timeline
- Pass Plans

Simulation Evaluation
- Debrief
- Critique
- Lessons Learned
- Recommendations

Implementation

Simulation Preparation

Simulation Management

Readiness Review

Conduct Simulation